SPLAT

The Sample Probe for Landing and Testing

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Abstract

Analysis is performed for the return of biological samples flown in space. Vehicle geometry is a 45° sphere-cone forebody. Spin stabilization is used to maintain passive stability and is supported by a drogue chute in the transonic regime. On-orbit maintenance and entry insertion is performed by a service module. The vehicle will land in the Utah Test and Training Range and be collected via helicopter to ensure rapid recovery of samples. The biological payloads placed restrictions of a maximum g-load of prolonged 16 g's and 20 g shock load. The trajectory was simulated as 3 DOF planar motion with landing dispersions being investigated through a Monte Carlo simulation. A pilot ringslot parachute provides initial deceleration and transonic stability and a main ringsail limits the final velocity. A hemispherical, vented airbag is used upon impact to meet g-loading requirements. SIRCA and Delrin compose the forebody TPS material and Li-900 is used for the backshell.

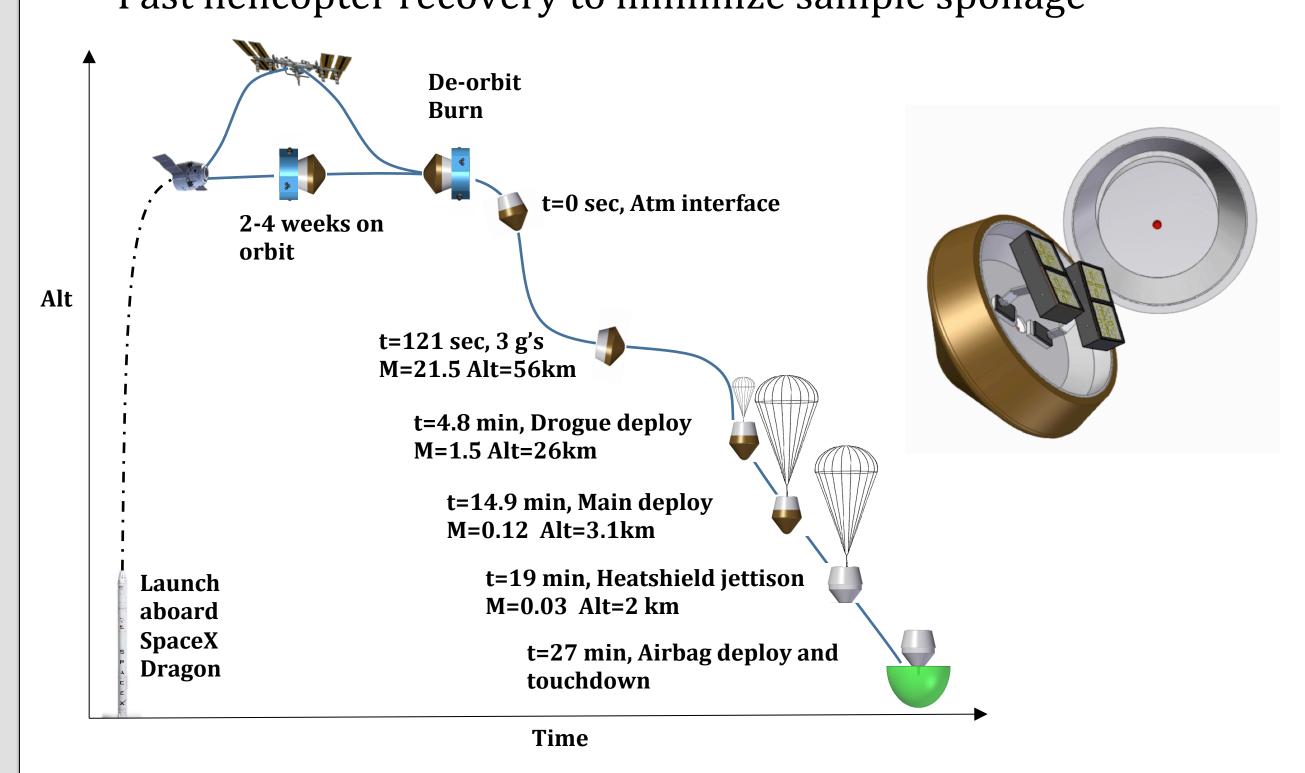
Introduction

- Mission concept: small reentry system for recovery of biological samples flown in space
- Free-flyer and ISS capable vehicle
- Heritage designs: Stardust, Mars Microprobe, SPORE
- Design constraints:
- Strict constraints to allow for widest possible range of biological samples

Mais Microprobe, SPORE		
Parameter	Limit	
Shock g-load	20 g's	
Sustained g-load	16 g's for 20s	
Payload Temperature	25 °C	
Recovery Time	< 6 hr	

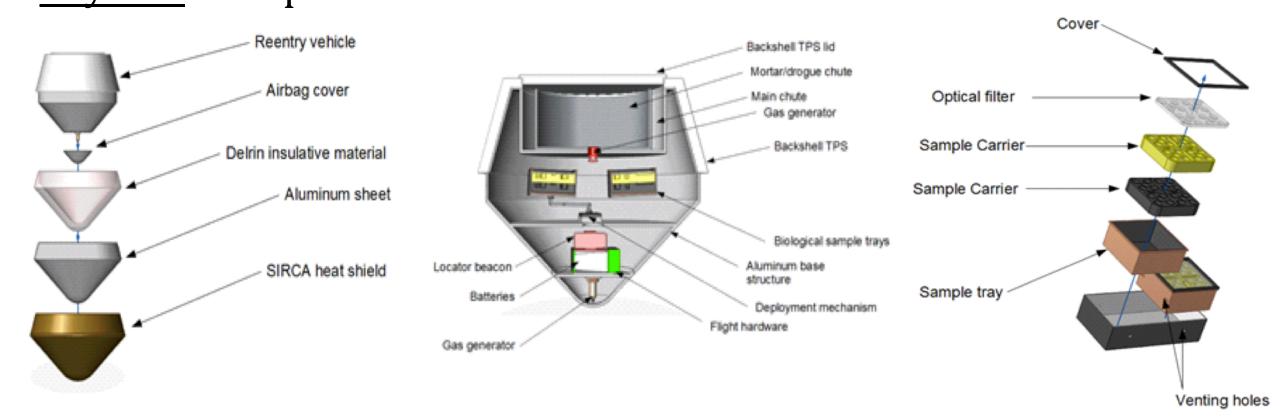
Concept of Operations

- Stowed in unpressurized trunk of SpaceX Dragon
- Configurable for attachment to ISS or as stand alone free-flyer
- Landing site: Utah Test and Training Range
- Large, flat area to target with high-precision tracking
- Fast helicopter recovery to minimize sample spoilage



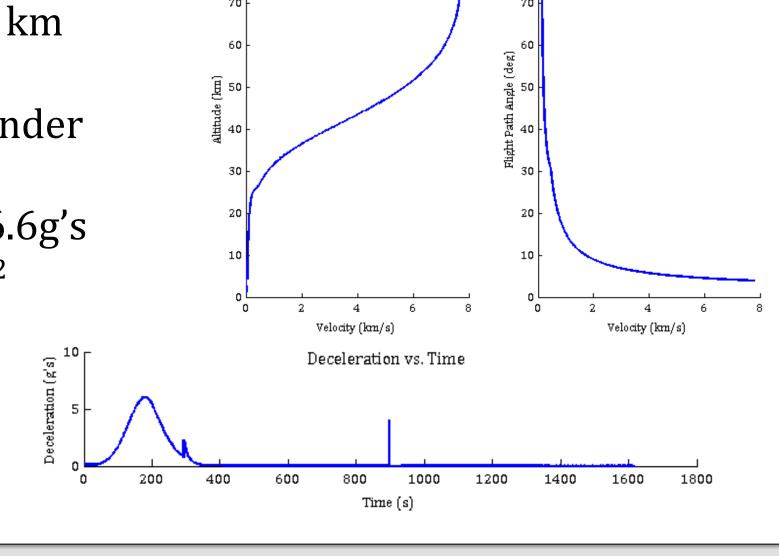
Geometry and Mass

- Configuration: Service module (entry insertion, on-orbit maintenance), entry vehicle (payload and support)
- Geometry: 45° sphere cone forbody, truncated cone aftbody
- Nose radius: 0.1m, max diameter: 0.48m
- Mass: 26.5kg, payload: 2kg, TPS: 11.5kg, decelerators: 5.5kg
- Payload: Sample carrier based on ESA EXPOSE module



Trajectory

- Entry conditions: V = 7.8 km/s, $\gamma = -4^{\circ}$ (for both ISS and free-flyer)
- Simulation: 3DOF planar EOM using US standard atmosphere
- MER Trajectory dispersion analysis (3σ) , UTTR nominal wind • Landing ellipse: 106 x 46 km
- (within UTTR) • Biggest effects: wind (under
- parachute) and γ • Maximum deceleration: 6.6g's
- Peak heating: 403 W/cm²



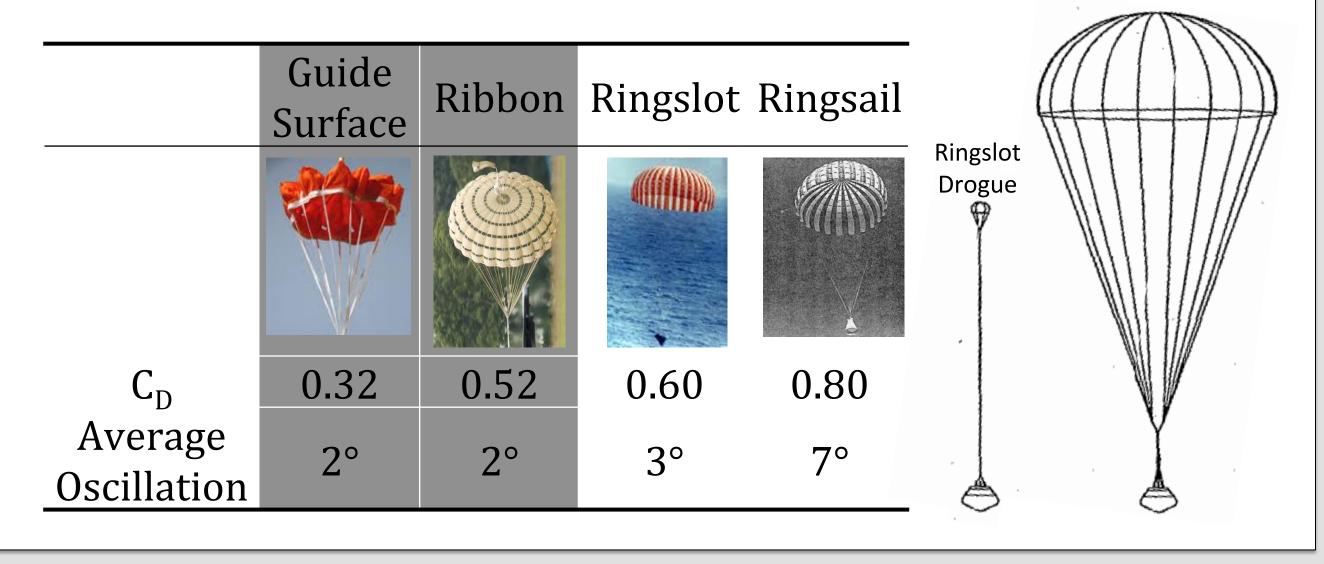
Thermal Protection System

- Temperature constraints:
- Payload: Expose (T<53°C), General biological sample (T<25°C)
- Bondline: TPS (T<250°C), Insulator (T<150°C)
- Simulation: 1D heat conduction w/ surface heat flux balance and coupled ablation modeling
- TPS Sizing: 3cm SIRCA and 3cm Delrin on forebody, 2.4cm LI-900 on backshell (includes 25% margin)
- SIRCA tested to 500 W/cm², but suggested for below 150 W/cm²

(unmargined)	Forebody	Backshell
PICA Thickness	8.18 cm	
PICA Recession	4.08 cm	
SIRCA Thickness	2.41 cm	7.63 cm
SIRCA Recession	0.13 cm	0.00 cm
Li-900 Thickness		1.89 cm
Peak Stagnation Heating	357W/cm^2	11W/cm^2
Peak Stagnation Pressure	0.86 atm	

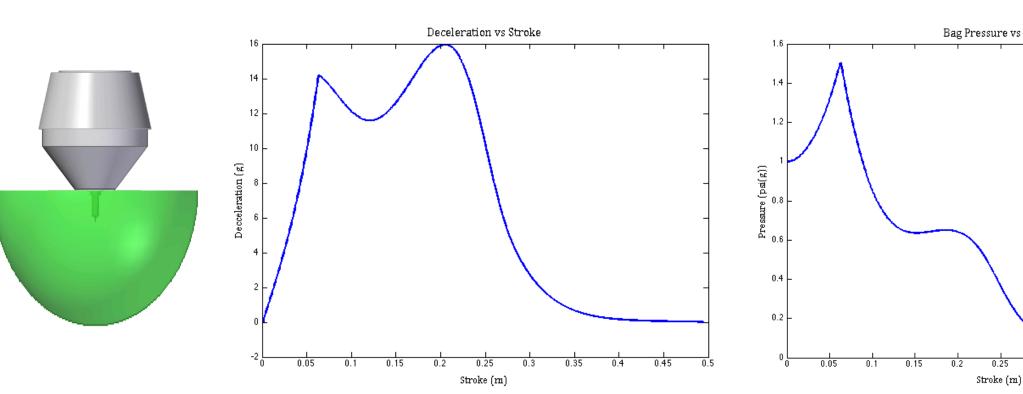
Parachute

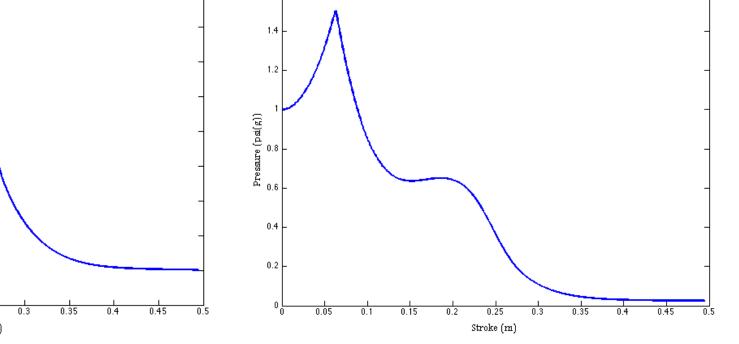
- Constraints: $N_{max} < 20g$'s, $V_{land} < 8.8m/s$, transonic stabilization
- <u>Drogue</u>: 0.5 m^2 Ringslot, mortar deployed at M = 1.5
- Main: 9 m² Ringsail, pilot deployed after 10min (M = 0.12)
- Results: Inflation load = 14g's, Landing velocity = 7.9m/s Ringsail



Airbag

- <u>Design</u>: Hemispherical vented airbag for off-vertical landing
- 0.5m radius, 1 psi(g) pressure, vents open at 1.5 psi(g)
- Results: Maximum load = 16g's (nominal), Stroke = 0.34m
- Load < 20g's for terminal velocity < 8.8m/s





Conclusion

- Vehicle design for reentry of a wide range of biological samples
- Analyzed: Mission, Landing Site, Geometry, Mass, Subsystems, Trajectory, TPS, Parachute, Airbag
- Max deceleration = 16g's, Max sample temperature = 25°C
- Landing at UTTR: tracking capability, quick recovery



Images: spacex.com, goldbergauctions.com, deist.com, globalspec.com, NASA.gov, Parachute Design Guide